Briefing to the ESSAAC
Technology Subcommittee (TSC)

on

Technology Development for Radiometry Antennas

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Process of Determining Technology Challenges

Measurement Parameters defined by ESTIPS:
http://esto.nasa.gov/estips

- Measurement Scenarios: 19 Included Passive Measurements (Final Count)

The Working Group Reviewed Measurement Scenarios

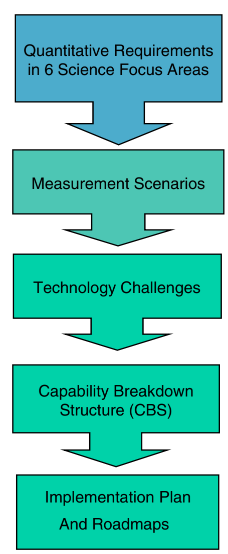
- Added scenarios that were missing: (A1, A2, H1, H2, H3, O1)
- Attempted to identify scenarios that were obsolete, or otherwise did not require technology development

Determined Technology Challenges Associated with Each Scenario

- Flowed Technology Challenges From the Measurement Scenario
- Passive Technology Challenges included Antenna, RF Electronics, Processing, and System Areas

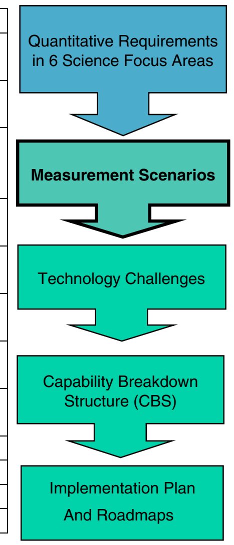
Developed Capability Breakdown Worksheet (CBS)

- Defined Tasks to Develop Each Technology Challenge
- Level of Effort, Beginning and Ending TRL, and Cost were Estimated



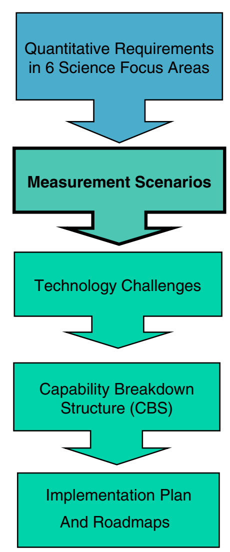
Measurement Parameters

Measurement Parameters	Focus Science Areas	Measurement Scenarios
Snow Cover, Accumulation and Water	Water & Energy Cycle	106, 107, 108, H2, C2
Freeze/Thaw Transition (Growing Season)	Water & Energy Cycle	H1
Global Soil Moisture	Water & Energy Cycle, Weather, and Climate Variability & Change	34, 38, 111, 177, H3
Global Precipitation	Water & Energy Cycle and Weather	67, 176, A1,A2
Sea Surface Salinity	Climate Variability & Change	34, 38, 111
Sea Surface Temperature	Climate Variability & Change	O1
Atmospheric Temperature	Water & Energy Cycle and Weather	67, 176
Atmospheric Water Vapor	Water & Energy Cycle and Weather	67, 176
Ocean Surface Winds	Weather	A2
Ozone Profile	Atmospheric Composition	140
Cloud System Structure	Atmospheric Composition	143
Wet Path Delay	Solid Earth (Geodesy)	53



Measurements and Scenarios

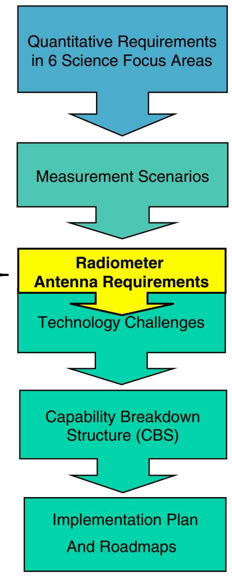
Radiometer Antenna Concepts	Criticality	Utility (scenario ID)
Real Aperture (25m) Rotating; 1.4+ GHz	Enabling	34
Real Aperture (25m) Torus; 1.4+ GHz	Enabling	111
2D STAR (25m) Scalable; 1.4+ GHz	Enabling	H1, H2, H3, 34
2D STAR (15 – 20m) Membrane; 1.4+ GHz	Enabling	177
Real Aperture (6-7m) Rotating 6-37 GHz	Enabling	106, O1
2D STAR (6m) 18/37 GHz	Enabling	107, C2
1D STAR (6x12m) 10/18/37 GHz	Enabling	108, A1, A2
Real Aperture (3-4m) 50/183 GHz	Enabling	176
2D STAR (3-4m) 50/183 GHz	Enabling	67
mmw/smmw/Far-IR (2-4m) 183+ GHz	Enabling	140, 143



Requirements of Future Radiometer Antennas

Trying to achieve:

1) **10 km Horizontal Spatial Resolution (HSR) from LEO at 1.4-GHz for Soil Moisture and Sea Surface Salinity**
2) **5 km HSR at 18- and 37-GHz for Snow Cover, SWE, Cold Lands Hydrology**
3) **50- and 183-GHz measurements from GEO with 3 – 4 meter aperture**
4) **Millimeter/Sub-millimeter wave antennas scanning and non scanning for atmospheric composition and limb sounding**
5) **10 km HSR at 6/10-GHz for SST**



Antennas For Future Radiometry Missions

1.4 GHz – 37 GHz		50/183 GHz and above
Rotating Reflector 25m (mesh) 1.4-GHz +	2D STAR 6m 18/37 GHz	2D STAR 3-4m 50/183-GHz
Deployable Stationary Torus 50x25m 1.4-GHz+	Rotating Reflector 6-7 m 6/10-GHz	Real Aperture 3-4m 50/183-GHz
2D STAR ~25m; Membrane 1.4 GHz +	1D STAR 6-7m 10 GHz +	mmw/smmw Scanning 2-4m 183 GHz +
2D STAR ~25m 1.4-GHz +		

Include capability up to Ka-band
with reduced effective aperture

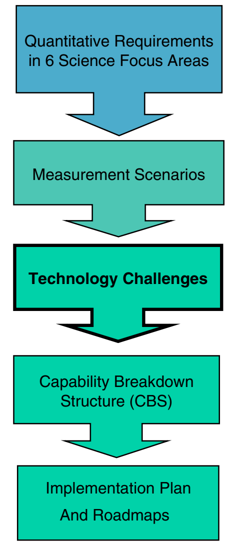
Definition of Technology Challenges

Define Technology Challenges for Radiometer Antennas

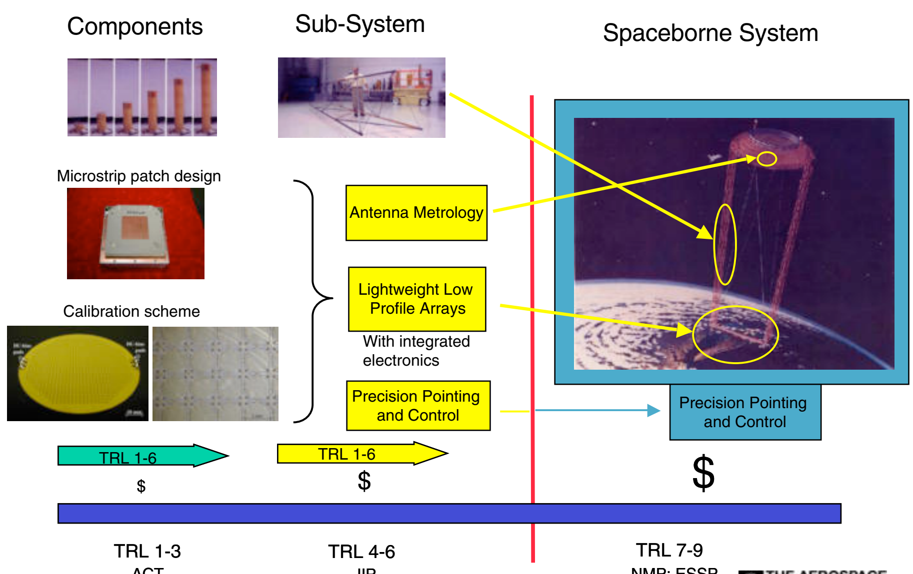
- Definition Based Upon Specific Antenna Concepts
  - Input Was Obtained From Technologists Within the Microwave Radiometry Community
- Consider the "Building Blocks" That Need Development
  - Extend Capability of Remote Sensing Measurements Within Program Constraints
  - Good Planning and Investment Provides Significant Cost Reduction in Advancing New Systems to Higher TRLs

Technology Challenges were Defined for All Antenna Concepts That Enabled Measurement of New Parameters

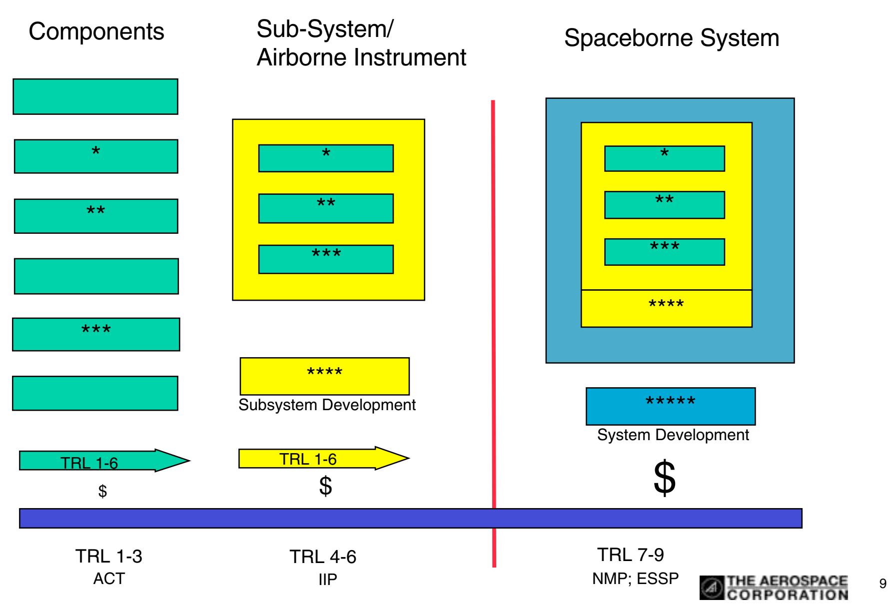
- Example: Torus Antenna is Provided Next



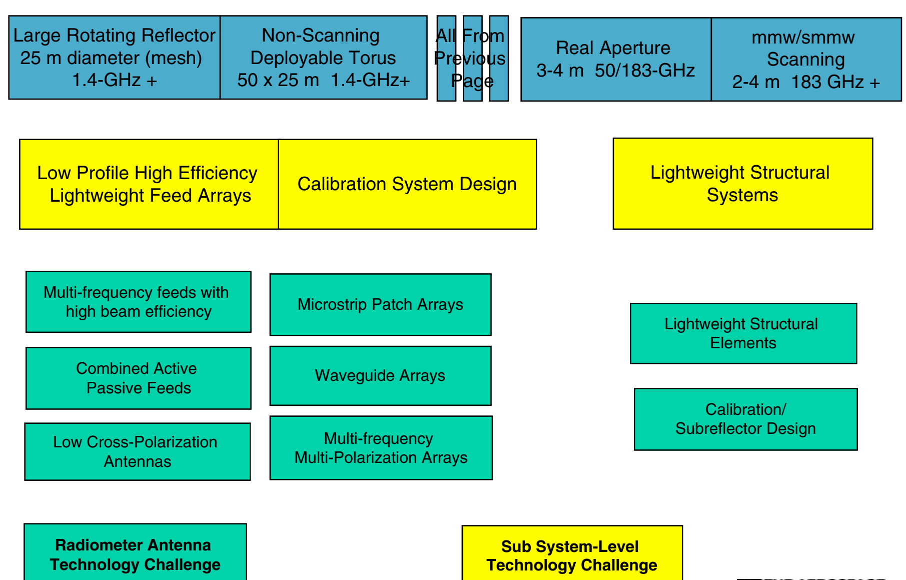
Technology Development Example (25x50m Torus)



Technology Development For Radiometer Antennas



Determining Technology Challenges



Derived Precision Control and Systems Challenges

Large Rotating Reflector
25 m diameter (mesh)
1.4-GHz +

Non-Scanning
Deployable Torus
50 x 25 m 1.4-GHz+

Real Aperture
3-4 m 50/183-GHz

mmw/smmw
Scanning
2-4 m 183 GHz +

Control of Spinning Large Apertures

Antenna Aperture Control

Antenna Metrology

Precision Pointing

Precision Control

Sub System-Level Technology Challenge

Technology Challenges for Future Radiometer Antennas

Antenna Component Items

- Multi-frequency feeds with high beam efficiency
- Combined Active Passive Feeds
- Low Cross-Polarization Antennas

- Lightweight Structural Elements
- Calibration/ subreflector design

Antenna Arrays

- Microstrip Patch Arrays
- Waveguide Arrays
- Multi-frequency Multi-Polarization Arrays

Precision Control and Systems

- Antenna Aperture Control
- Precision Control
- Precision Pointing
- Control of Spinning Large Apertures
- Antenna Metrology

System Level Designs

Deployable – Large Aperture
- Large Rotating Reflector 25 m diameter (mesh) 1.4-GHz +
- Non-Scanning Deployable Torus 50 x 25 m 1.4-GHz+
- Real Aperture 6-7 m 6- and 10-GHz
- Real Aperture 3-4 m 50/183-GHz

Precision Inflatable Deployable Structures
- 2D STAR Membrane ~25 m; 1.4 GHz +
- 2D STAR ~25 m;1.4-GHz +
- 2D STAR ~6m; 18/37-GHz
- 2D STAR 3-4 m 50/183-GHz
- 1D STAR 3x6 m; 10 GHz +

Millimeter wave and Sub-mmw Antennas
- mmw/smmw Scanning 2-4 m 183 GHz +

Antenna Technology Histogram

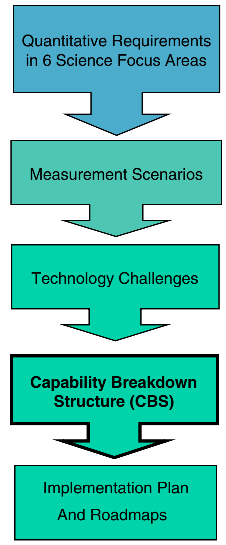
Antenna Technology Challenge	Scenario Count	Parameter Count
Antenna Component Items		
Multi-frequency feeds with high beam efficiency	14	10
Combined active passive feeds	11	6
Low Cross polarization antenna elements	6	4
Antenna Arrays		
Waveguide arrays	6	4
Microstrip Patch arrays	11	6
Multi frequency multi-polarization arrays	16	11
Feed clusters/focal plane arrays	13	9
Structural Elements		
Lightweight structural elements	12	10
System Level Designs		
Precision deployable/inflatable structures (other than reflectors)	8	6
Deployables large aperture	9	7
Millimeter wave/Submillimeter Wave antennas	4	5

Antenna Technology Histogram (Cont'd)

Precision Control and System Challenges	Scenario Count	Parameter Count
Precision Control		
Precision Antenna Pointing (momentum compensation)	3	4
Antenna Metrology	8	7
Precision Thermal Control	6	4
Control of Spinning apertures (balancing)	4	4
System		
Cryo-Cooler	1	1

Radiometer Antenna Technology Developments

The Next Charts Will Describe Detailed Developments from the CBS



Low Profile Lightweight Low-Loss Array Feeds

For STAR and Pushbroom arrays


Current Status

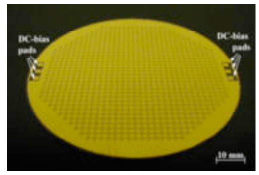
1. L-band single elements and small arrays of dual-polarization patch antennas with good bandwidth and polarization properties have been demonstrated. However, these utilize relatively heavy standard teflon-glass laminates, and are not viable for 25 m length linear arrays for 2-pol and 3-pol operation.
2. X-, Ku-, and Ka-band STAR or pushbroom arrays require novel antenna designs that can provide low loss dual-polarization conical scan.

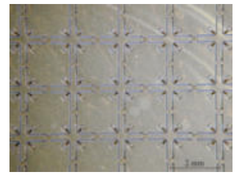
Tasks needed

1. Demonstrate performance of sub-array configurations using lightweight laminations of multiple stacked patches on thin substrates with foam or other low relative dielectric constant layers, adaptable to 1D or 2D STAR arrays.
2. Hybrid patch arrays on thin substrates excited by waveguide crossed-slot arrays and combined with shaped reflectors need to be developed and demonstrated.
3. Expand on current waveguide array (WGA) designs (e.g. LRR airborne instrument) with higher frequencies, wider bandwidths, dual-polarization and conically-scanned versions
4. Model and trade cross polarization levels of Microstrip (MS) patch and WGA elements with other parameters during development
5. Develop and demonstrate antenna feed system that meets L-band bandwidth 1.26 – 1.4 GHz, isolation and beam efficiency requirements for shared active/passive aperture

Current TRLs: (3) Array performance
(2) Lightweight materials
Exit TRL: (6)

Steerable Subreflectors
For Calibration of Large Apertures Radiometers





Concept

MEMS-switched frequency selective surface (FSS) dual frequency sub-reflector

Provides the ability to electrically steer large focal plane and focal line arrays away from main reflector and to cold space for end-to-end system calibration

Apply to FPA for torus antenna – and/or other antenna concepts

Status

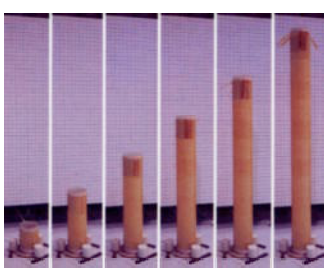
1. Frequency/reflectivity selective surface (RSS) concept applied to radiometry: TRL 2
2. Other concepts needed for end-to-end calibration

Tasks needed

1. Adapt existing MEMS-based Frequency Selective Surface technique to RSS application (TRL 2 – 3).
2. Develop a prototype RSS based subreflector antenna system. Characterize loss, reflectivity, impact on other radiometer figures of merit.
3. Develop a focal line array using RSS subreflector (TRL 3–4).
4. Combine RSS focal line array with laboratory radiometer and verify system calibration and stability (TRL 4 to 5).
5. Build field deployable instrument and use in science campaign. Verify ability to retrieve Level 2 EDRs with acceptable accuracy and uncertainty. (TRL 5 to 6).

Current TRL: 2
Exit TRL: 6

Lightweight Structural Elements



Tasks needed

1. Trade study involving best candidate concepts for support elements integrated with the desired electronics/antenna elements
2. Develop the structural support arm concept, build a nondeployable version and test structural characteristics
3. Develop deployable arm/column
4. Deployment test and structural characteristics test/verification

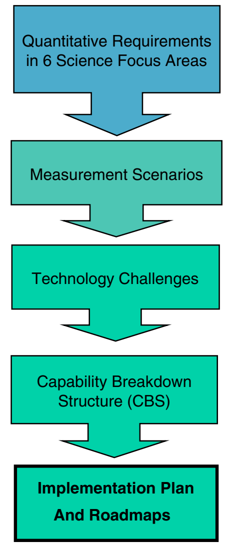
Requirements

1. Less than 0.1 kg/m and must be able to support distributed science sensing element mass, data and power cabling integrated into the structure
2. Self Correcting to $\lambda/20$ (RMS) surface distortion

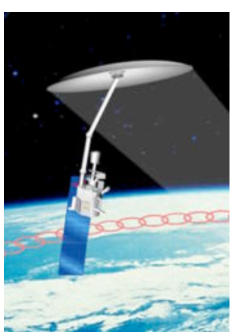
Current TRL: 3
Exit TRL: 6

Detailed Radiometer Antenna Developments

The Next Charts Show Developments from the of the Specific Radiometer Antenna Concepts



Large Rotating Reflector



Tasks needed for 6 – 20 m rotating reflector

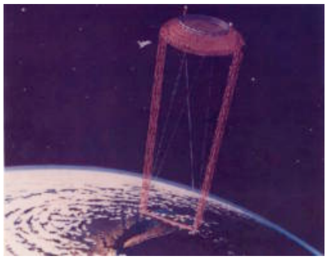
1. Develop optimal system design based on science requirements
2. Lightweight deployable reflector
3. Design reflector boom feed stowage relative to projected designs and capabilities
4. Develop and test multi frequency multi-polarization horn or patch feed design matched to reflector geometry to meet overall beamwidth, beam efficiency and cross polarization requirements
5. Design and test momentum compensation and balancing
6. Analyze thermal and mechanical distortions, calibration system, and overall system error budget and performance
7. In support of #3 develop antenna metrology and compensation techniques to ensure minimum performance can be met

Current Status

1. HYDROS – 6m rotating aperture: scheduled for launch in 2009
2. Feedback suggests 20 – 25 m may be upper range of feasibility for rotating aperture – for larger apertures should consider stationary parabolic torus antenna – system trades involving industry are needed

Current TRL: 4
Exit TRL: 6

Large Deployable Non-Rotating Reflector Antenna (Torus)



Tasks needed in support of ~50 m parabolic torus

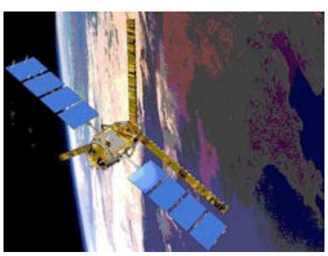
1. Develop optimal system design based on science requirements
2. Design reflector boom feed stowage relative to projected designs and capabilities (50m X 25m parabola)
3. Develop and test multi frequency multi-polarization subreflector and patch array feed design matched to the reflector geometry to meet overall beam width, beam efficiency and polarization requirements
4. Design and test momentum compensation (for the feed system) and balancing
5. Analyze thermal and mechanical distortions, calibration system, and overall system error budget and performance
6. In support of #3 develop antenna metrology and compensation techniques to ensure minimum performance can be met

Current Status

1. HYDROS – 6m rotating aperture: scheduled for launch in 2009
2. Feedback suggests 20 – 25 m may be upper range of feasibility for rotating aperture – for larger apertures should consider stationary parabolic torus antenna – system trades involving industry are needed

Current TRL: 4
Exit TRL: 6

2D STAR
With Antenna Feedhorns



Tasks needed to support STAR development

1. Scalability for GEO flight design concepts
2. Extrapolate design to 183 GHz case
3. Low recurring cost for large scale fabrication of identical units
4. Evaluate different feedhorn options: conduct camber test and modify feedhorn design as needed
5. Integrate into laboratory interferometer testbeds
6. Integrate into field deployable prototypes
7. Conduct thermal and mechanical studies in parallel with above

Requirements

1. Flood beam element patterns with ultra-low mutual coupling, low-loss, and ultra stable phase center location vs. temperature
2. < 30dB mutual coupling between immediately adjacent antennas
3. < 0.2dB ohmic losses below 50 GHz; <0.3dB at 50/60, 183 GHz
4. Phase center stability to $\lambda/100$ over –40 to +40C temperature range

Status

1. Current GEOSTAR prototype has adequate performance for an electrically-small design

Current TRL: 3+
Exit TRL: 6

2D STAR

With Ultra-lightweight Elements and Tensioned Membranes

Tasks needed to support STAR antenna development

1. Develop ultra-lightweight deployable antenna technology using tensioned panels and membranes with integrated RF electronics and antenna elements
2. Develop non-deployable test article
3. Develop antenna metrology and aperture control methodology
4. Characterize structural dynamics
5. Integrate low power radiometer electronics onto/into antenna element and structure in a non-deployable scale model
6. Develop flight like tensioned membrane panels
7. Analyze thermal and mechanical distortions and investigate thermal monitoring of micro-miniature electronics

Current Status

1. STI -- Phase 0 studies ongoing
2. One-third scaled test article under development

Current TRL: 2+
Exit TRL: 4-5

Requirements

1. $\lambda/20$ RMS
2. ~20m (full size) diameter
3. Lightweight, low loss integrated arrays

1D STAR

With Lightweight ~6m parabolic cylinder reflector

Tasks needed for 1D STAR development

1. Demonstrate lightweight reflector/feed system deployment and electrical performance.
2. Design reflector and support structure.
3. Design high efficiency, low mutual coupling, lightweight line feed array compatible with antenna structure; dual frequency/dual polarization
4. Lightweight compact 6x12-m parabolic cylinder reflector
5. Antenna metrology and compensation of reflector distortion

Requirements

1. Dual polarization at 18 & 37 GHz.
2. Spatial resolution of 5-km with similar imaging performance compared to a real aperture conical imager.
3. Large (>6x12 meter) cylindrical parabolic reflector fed by linear feed - stowable/deployable.

Status

1. Study underway at BATC
2. Measurement scenario 108

Current TRL: 3
Exit TRL: 6

Millimeter Wave and Sub-mmw Measurements
for Ozone Profile and Atmospheric Composition

MLS instrument on EOS Aura

Tasks for reducing schedule/cost risk in development

1. Demonstrate mathematical design (using geometrical and physical optics) that allows very broad scanning in azimuth
2. Develop a structural concept for the scanning antenna system with fabrication of breadboard units

Antenna System Requirements

1. Antenna system for scanning Earth's limb with ~2 km vertical and ~20 km horizontal resolution at 200 GHz
2. Reflector surface accuracy of ~10 micrometers
3. Capability of vertically-scanning ~ 1 degree in ~10 s, and azimuth scanning ~ ±75 degrees in ~0.5 s.

Current Status

1. A conceptual design exists to meet the requirements listed in measurement scenario 140

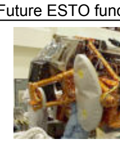
Current TRL: 2
Exit TRL: 4 - 5

Passive Antenna Integrated Technology Roadmap (2004-2015)

Current ESTO funding
Future ESTO funding

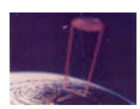
Low profile lightweight array feeds — 2004 – 2008: Develop multi frequency, low insertion loss <1.0 dB, dual polarization arrays

mmW/smmw scanning antenna — 2014: Breadboard optical system, develop structural concept

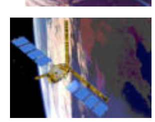


Mechanically scanning aperture for mmw (GEO) — 2009: Aperture control, momentum compensation, GEO

Rotating large aperture low frequency — 2010: Reflector/boom/feed stowage, dynamic balancing, multi-polarization multi-frequency feed (20-25m L-band)

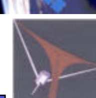


Torus with electronically scanning feed array — 2010: Develop scale model, focal line arrays, adaptive sub-reflector



2D-STAR with receiver elements — 2012: Integrate in laboratory testbeds; integrate into field deployable Prototypes, perform thermal and mechanical studies in parallel

2D STAR with membrane WG technology — 2014: Develop ultra-lightweight deployable antenna technology using tensioned panels and membranes, characterize mechanical and thermal properties



Capability Thresholds

10km L-band; 5km K-band measurements from LEO; 50/183 GHz measurements from GEO; Sub-millimeter wave scanning limb measurements; combined active/passive measurements

Back Up Slides

Measurement Scenarios for Passive Remote Sensing

Hydrology

- 2D STAR; 25 meter diameter L-band
- Rotating real 25 meter real aperture
- 2D STAR 6m; Snow Water Equivalent (SWE) L, C, X, W-band
- 1D STAR 18- and 37-GHz

Atmosphere

- Tropospheric Ozone; 140
- Cloud Structure; 143
- Precipitation and Atmospheric Temperature, 67
- Ocean Surface Winds and Precipitation A1, A2

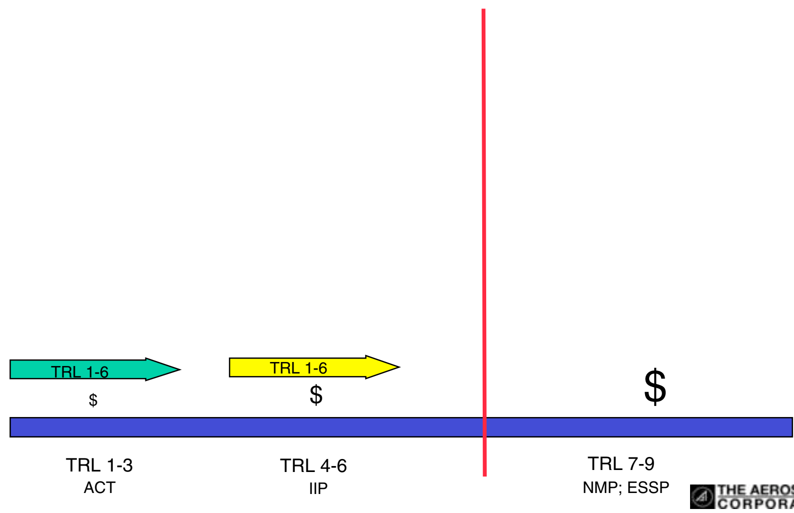
Oceans

- Sea Surface Salinity

Cryosphere

- Snow Cover 19 – 37 ; 6m

Technology Development (Example 2)



Large Aperture Radiometer Antenna Building Blocks

- Microstrip Patch Arrays
- Multi-frequency Multi-Polarization Arrays
- Multi-frequency feeds with high beam efficiency
- Combined Active Passive Feeds
- Low Cross-Polarization Antennas
- Waveguide Arrays

- Lightweight Structural Elements
- Calibration/ subreflector design

- Antenna Aperture Control
- Precision Control
- Precision Pointing
- Control of Spinning Large Apertures
- Antenna Metrology